Nitrogen and Sulfur Nutrition and at Planting Application in Corn and Soybean Production

Raun Lohry, Ph.D.

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Introduction

- Background
- Why talk about N and S?
  - Common elements and continuing work on their best use
  - S becoming more commonly used in SB production
  - You need to be able to provide an answer to customer questions

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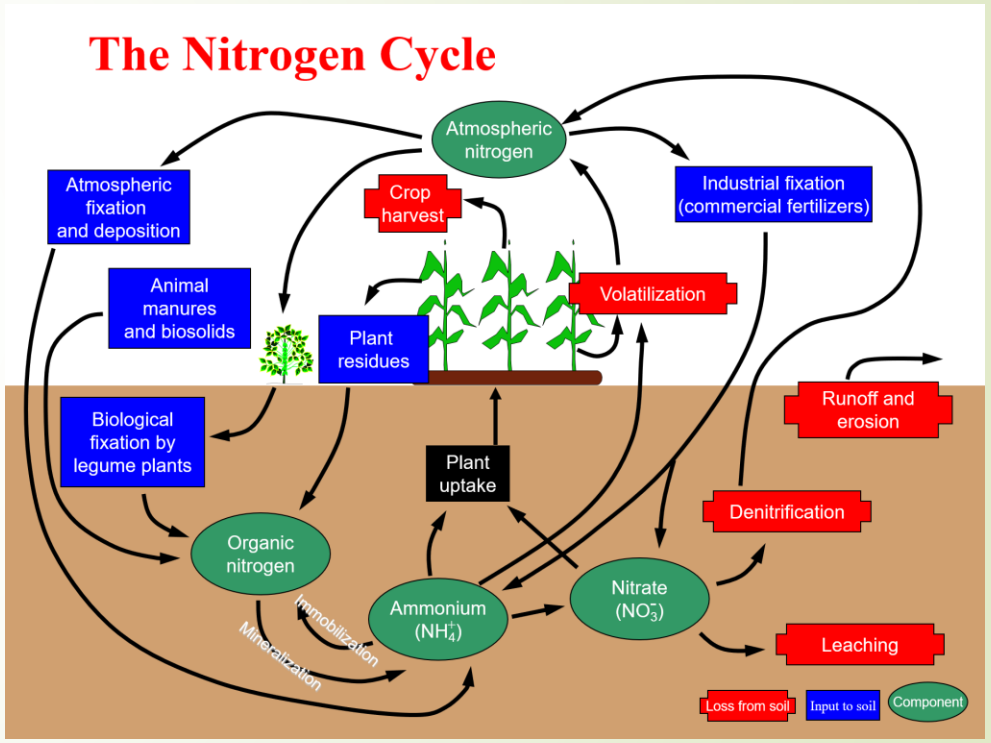
Nitrogen interactions

- Production:
  - Predominate form of fertilizer N production is Haber Bosch synthesis
  - Nitrogen Cycling
  - N Losses
    - Crop removal
    - Volatilization
    - Erosion
    - Denitrification
    - Leaching



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Nitrogen Functions

- Agronomic crops use both nitrate (NO_3^-) and ammonium (NH_4^+)
  - NO_3^- moves with soil water while NH_4^+ tends to be less mobile.
- Used in large amounts by crops

Corn	200 bu	275
Soybeans*	60 bu	315

- Chlorophyll production, photosynthesis, protein synthesis, utilization of sunlight, nutrient uptake, certain vitamins, amino acids, energy systems

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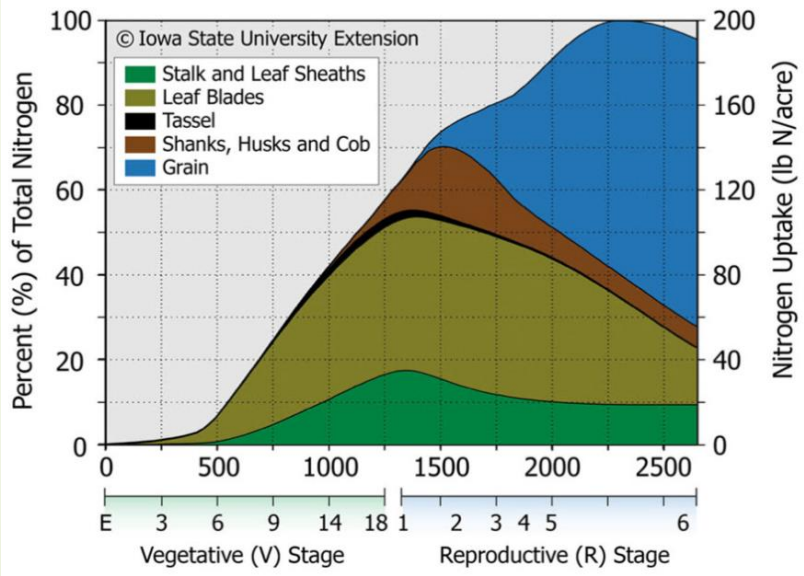
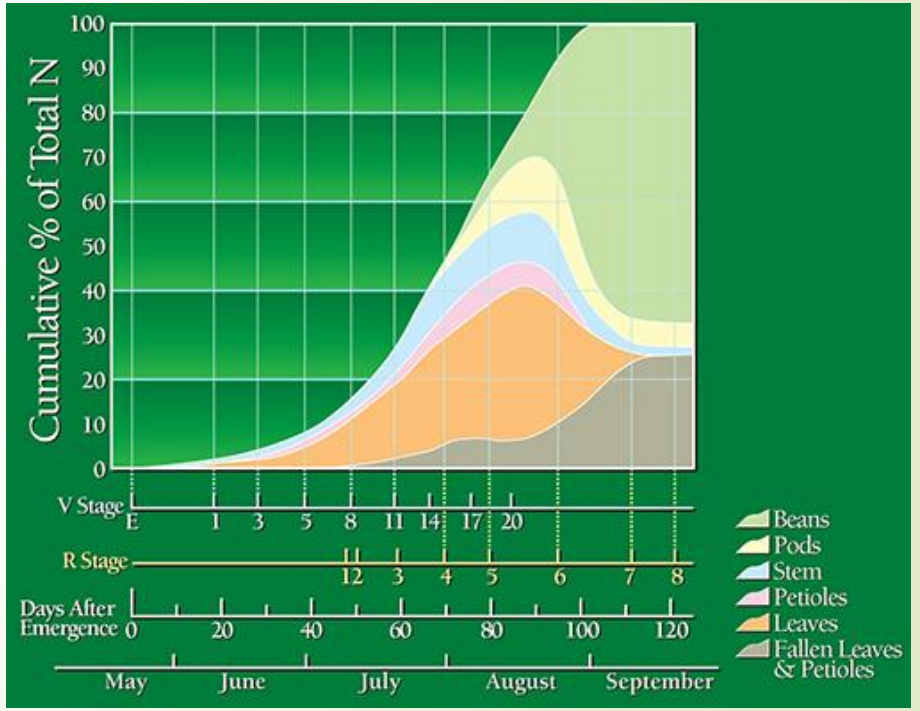
Nitrogen Uptake in Corn and Soybeans

Corn



Soybean



https://store.extension.iastate.edu/

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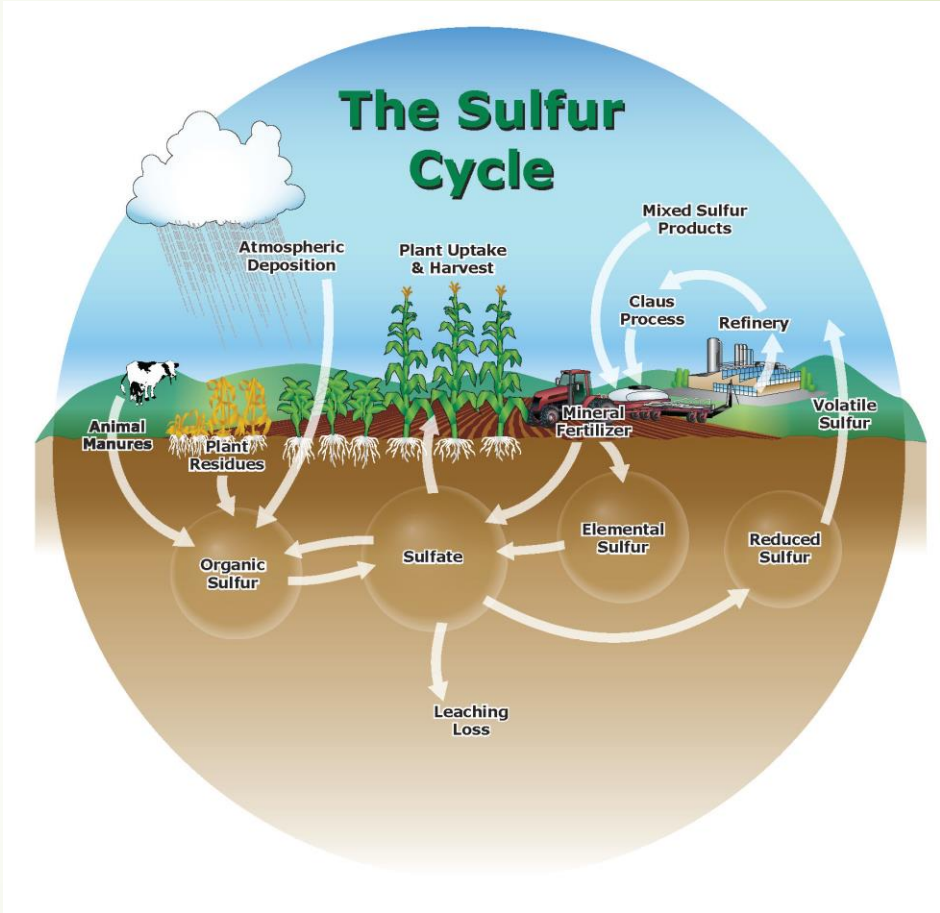
Sulfur interactions

- Plants take up sulfur primarily as sulfate ($SO_4^=$), but can also absorb sulfur dioxide (SO_2) gas through their leaves
- Is a constituent of protein
- Helps develop enzymes and vitamins
- Promotes nitrogen fixation by legumes
- Aids in seed production
- Is necessary for chlorophyll formation
- Nodulation co-factor



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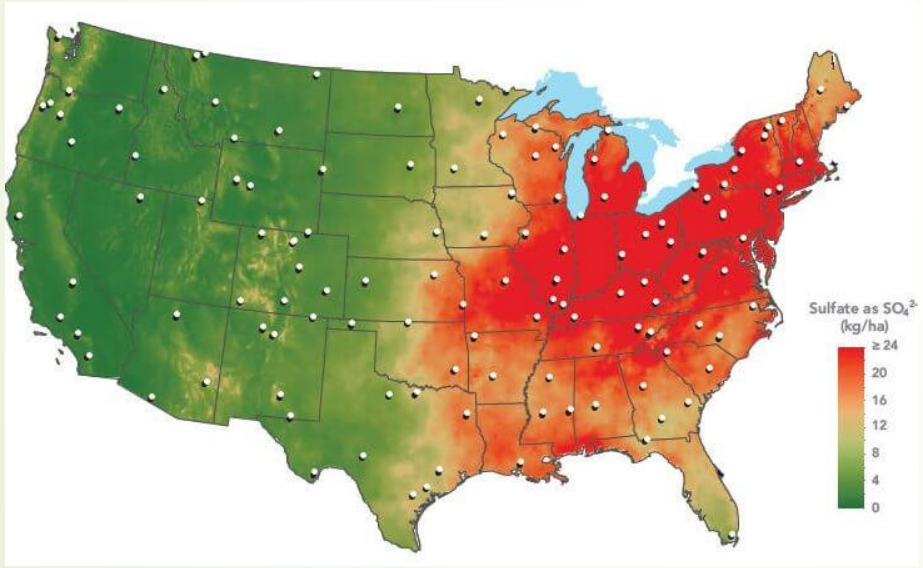
Why we need to add sulfur

Sulfate deposition 1985



https://www.calciumproducts.com/products/so4/

Sulfate deposition 2016

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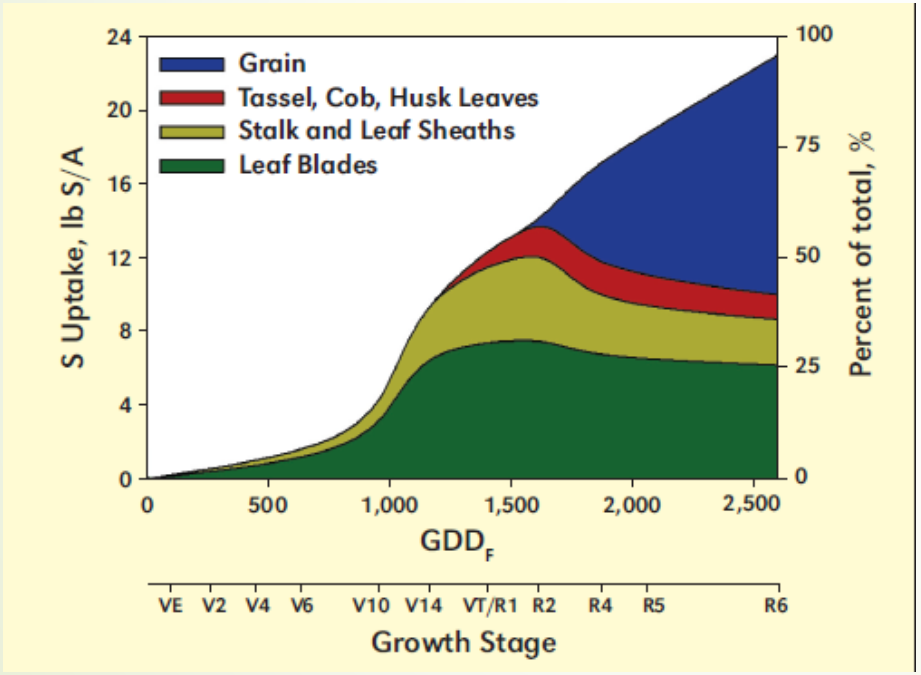
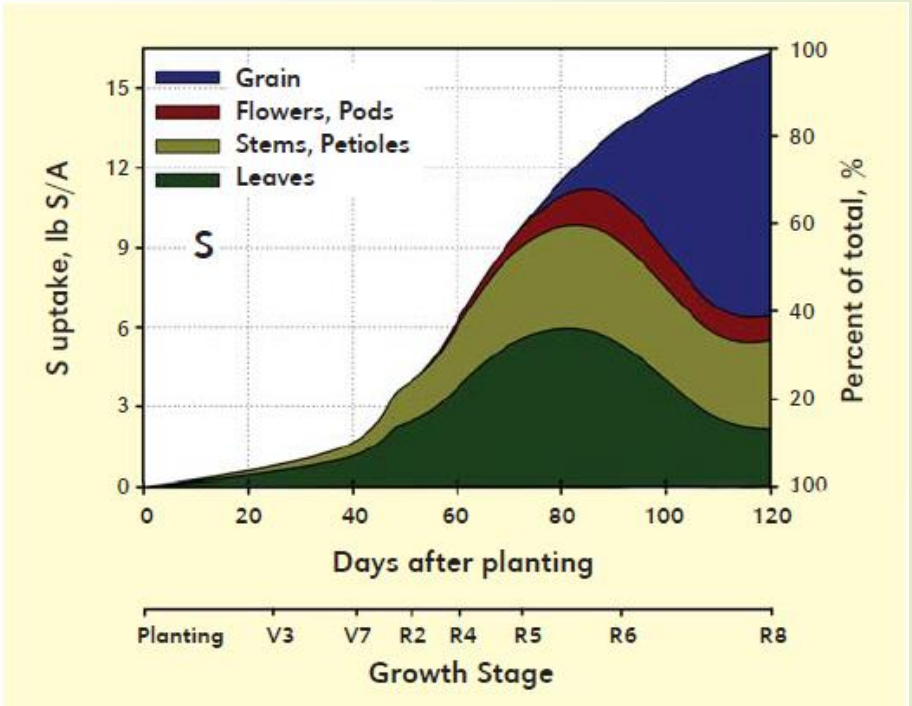
Sulfur Uptake

Corn (200 bu/ac)



Soybean (60 bu/ac)



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Nutrient Forms

- Natural Sources of Sulfur
  - Soil organic matter
    3-5 lb./ac %OM
  - Animal manure
  - Irrigation water
    5-10 + lb.ac
  - Atmosphere
    5-7 lb.ac

Inorganic Sulfur Sources

Product	% S
Ammonium sulfate	24
Ammonium thiosulfate	26
Ammonium polysulfide	40-50
Potassium sulfate	18
Potassium sulfite	8
Potassium - magnesium sulfate	22
Elemental sulfur	>85
Gypsum	12-18
Magnesium sulfate	14
Potassium thiosulfate	17

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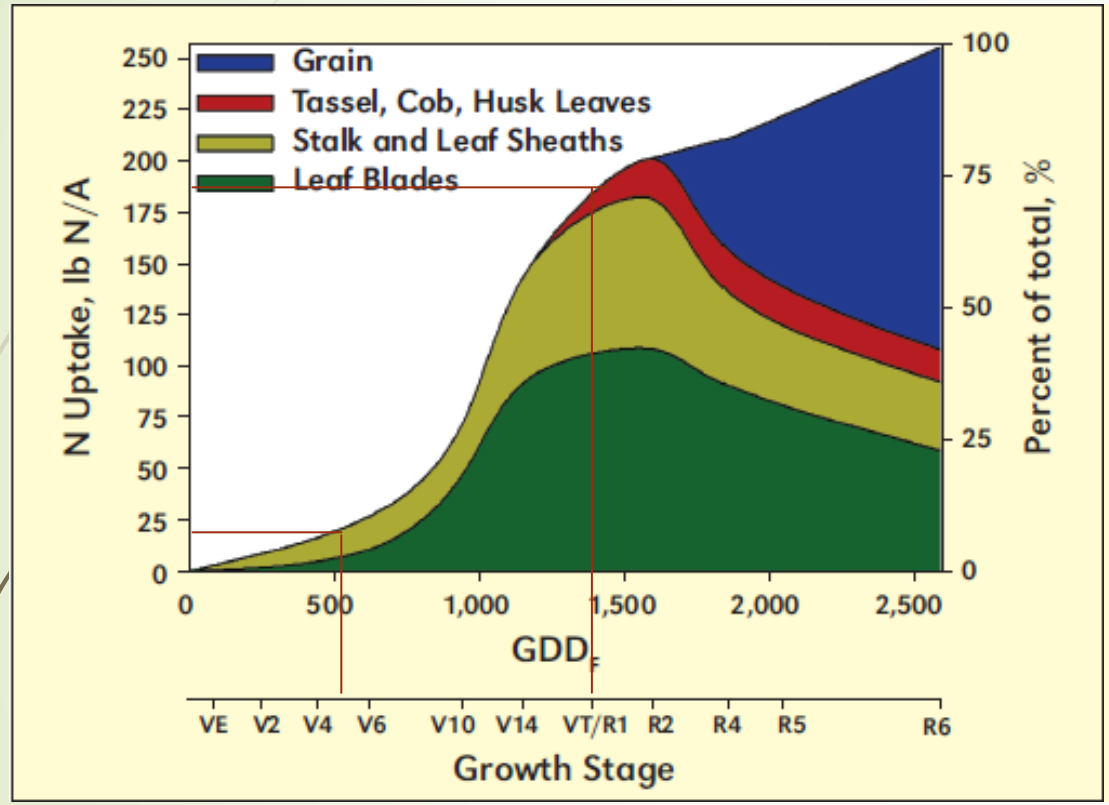
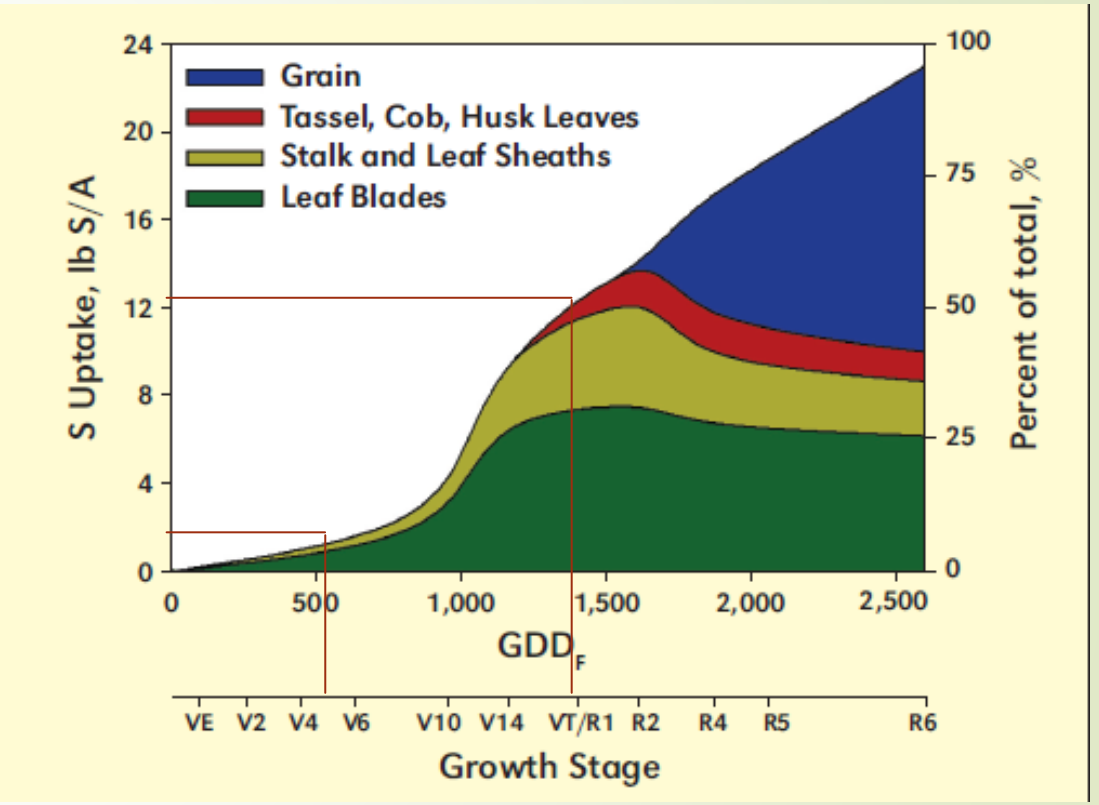
Nitrogen and sulfur uptake in corn V5 & VT





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Corn Response When Both Nitrogen and Sulfur Are Applied

S Rate	0 Lb N/ac	75 Lb N/ac	150 Lb N/ac	Average
0	63	128	145	112
10	79	143	153	125
20	92	146	155	131

Potash Phosphate Institute

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Nitrogen and Sulfur Interactions - Corn

Treatment	Clintion, IL	LSD(0.10) = 10.8 bu/ac	Clay Center, KS	Bridgewater, SD
No Sidedress	272	b	234.3	211.3
50 lb N	278	ab	240.8	207.8
50 lb N + 25 lb S	277	ab	244.4	219.1
75 Lb N	285	a	253.4	211.1
75 lb N + 25 lb S	288	a	250.8	223.9

Treatments applied at V5-V6
Fertilizer Sources: UAN and ATS
GoldenHarvest 2020

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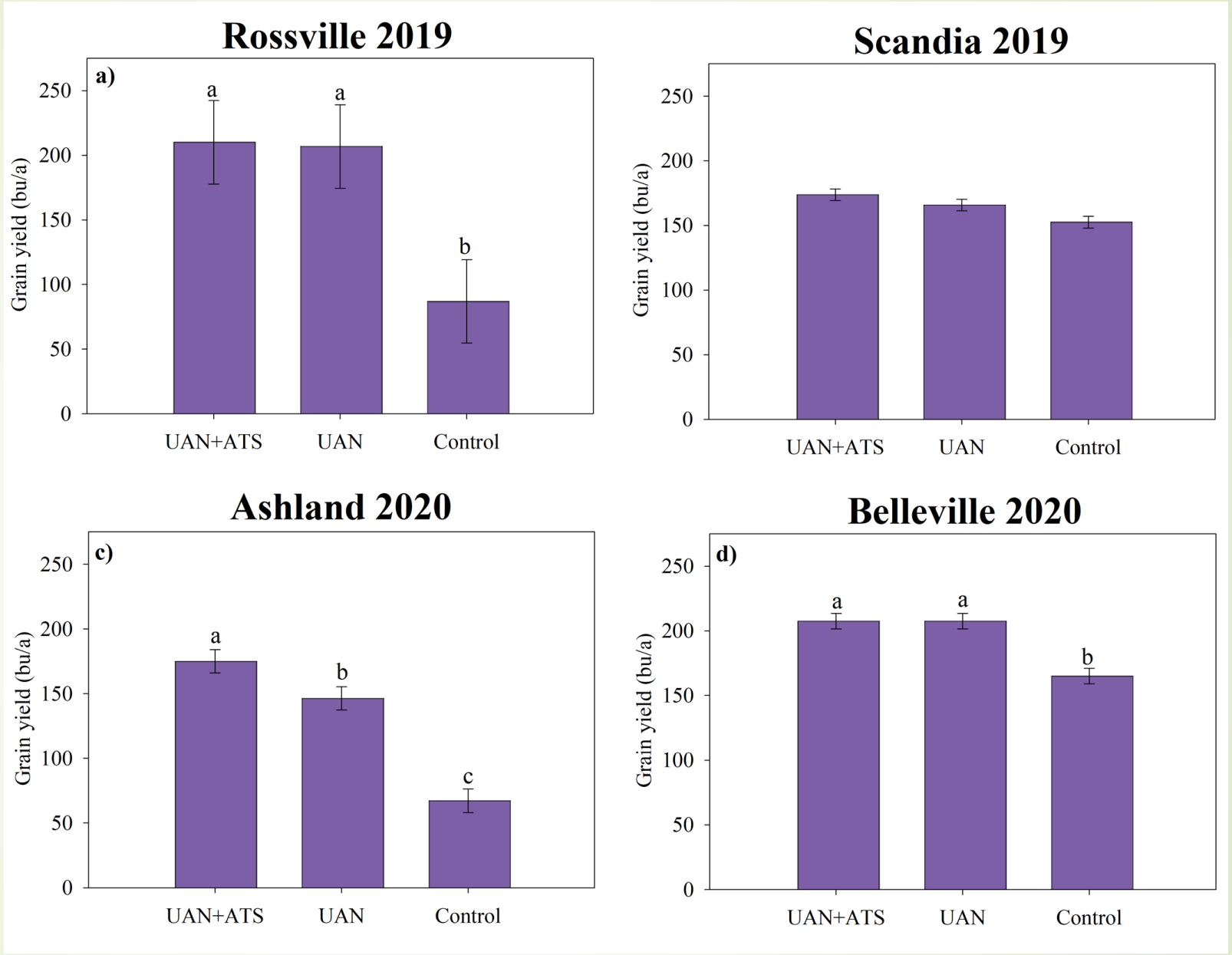

Corn Yield Response to Sulfur Applied with Nitrogen Fertilizer

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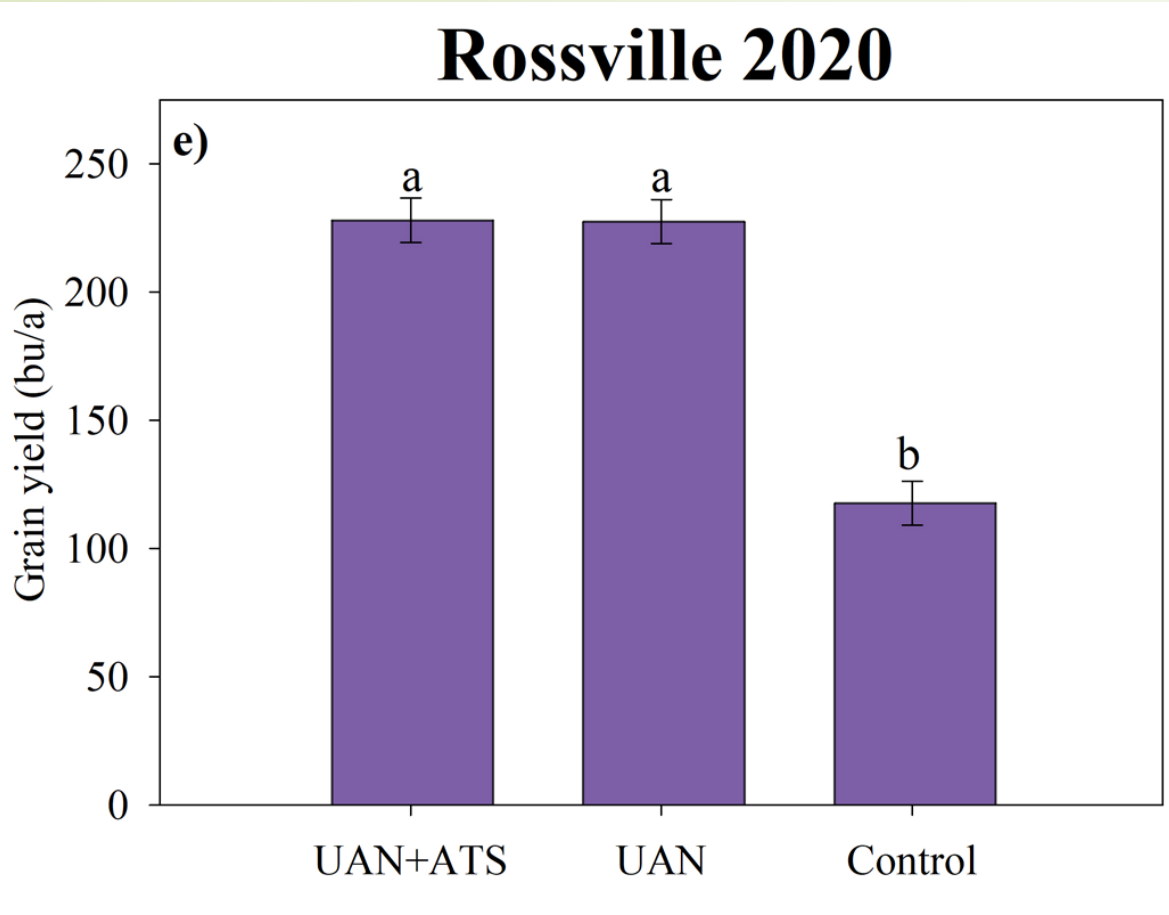

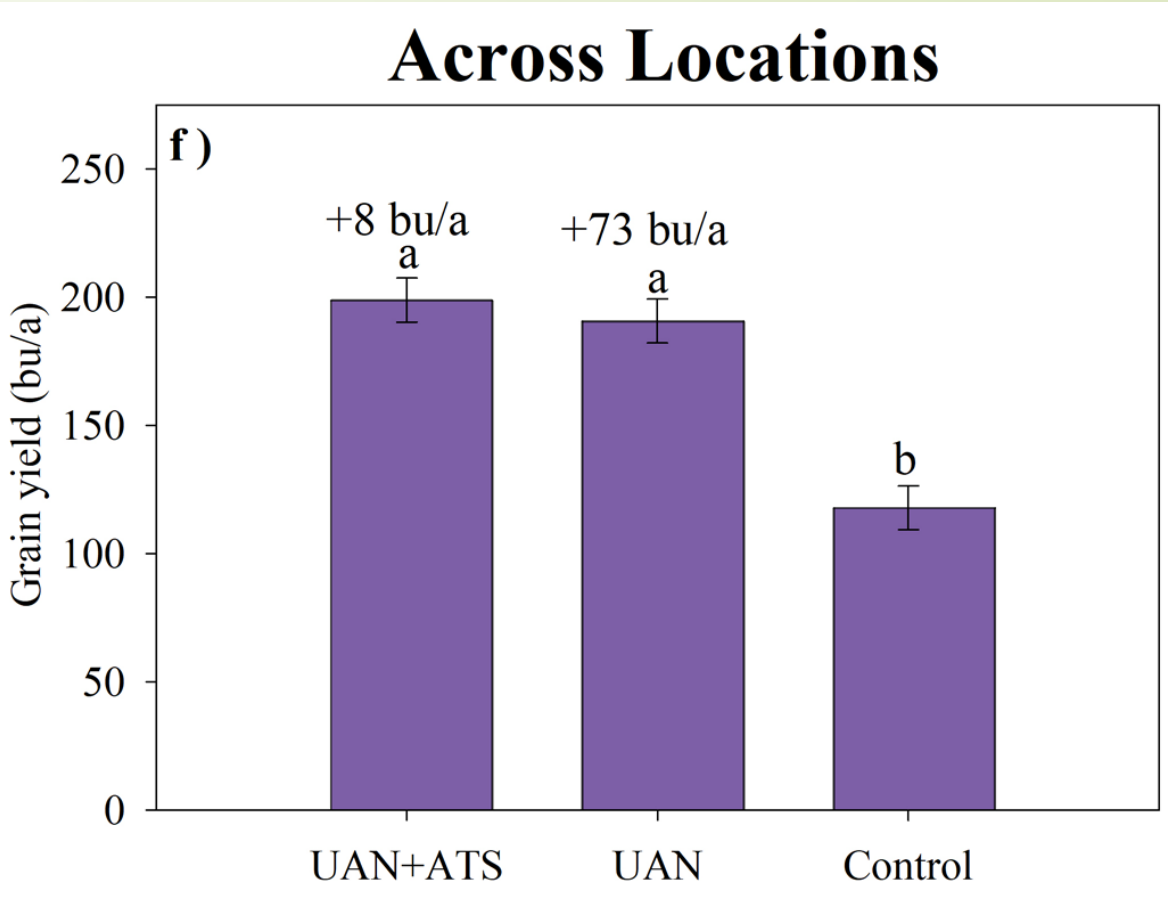

Grain yield for all five locations and average across locations in Kansas. Error bars indicate standard error of the mean and mean values followed by the same letter are statistically different ($P < 0.05$). Treatments: 1) a control with no sulfur and no nitrogen; 2) urea ammonium nitrate (UAN) (180 lb N/a; 0 lb S/a); and 3) UAN plus ammonium thiosulfate (ATS) (180 lb N/a; 15 lb S/a).

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T.E. Husa and D.A. Ruiz Diaz, 2021

2020 N+S x Planting Date

Treatment	Timing	N	S
		lb N/ac	lb S/ac
UTC	.		
AMS	PRE	17.5	20
ATS	PRE	9.3	20
AMS + Urea	PRE	40	10
AMS + Urea	V4*	40	10
V4 + R3	V4*+ R3 Dr	80	20
AMS + UAN	R3 Direct	40	10
UAN	R3 Direct	40	.
Gypsum 10	PRE	.	10
Gypsum 20	PRE	.	20

2020 N+S x Planting Date

				Yield			
Treatment	**Timing**	**N**	**S**	**12-May**		**8-Jun**	
		lb N/ac	lb S/ac	bu/ac			
UTC	.			61.9	de	61.9	de
AMS	PRE	17.5	20	79.8	a	68.6	bcd
ATS	PRE	9.3	20	76.0	ab	66.1	de
AMS + Urea	PRE	40	10	82.6	a	66.5	cde
AMS + Urea	V4*	40	10	81.3	a	65.0	de
V4 + R3	V4*+ R3 Dr	80	20	83.0	a	69.7	bcd
AMS + UAN	R3 Direct	40	10	70.7	bcd	65.0	de
UAN	R3 Direct	40	.	68.0	bcd	59.1	e
Gypsum 10	PRE	.	10	76.7	ab	68.5	bcd
Gypsum 20	PRE	.	20	75.2	abc	66.7	cde

N+S x Planting Interactions

- **EARLY** planting still proves to increase yield.
- **N+S Fertility** increased yield in **EARLY** planted soybeans in 2018 and 2020 (10+ bu/ac)
  - Consistent protein concentrations in 2018 and 2020 TBD
- **N+S Fertility** did not affect the yield of **LATE** planted soybeans in 2018, 2019, 2020.
- **Cool and/or wet conditions** associated with **EARLY** plantings likely increased the yield response to the **N+S Fertility** due to limited mineralization of soil organic matter and slow soybean growth (roots, nodules).

NS Fixation: 21 W. Lafayette

Fertilizer	Nitrogen	Sulfur	Yield
UTC	0	0	61.4
AMS	26	30	75.8
Gypsum	0	30	75.0
Urea	26	0	62.4
Full NS	150 + 150	15 + 15	77.7
	Pre + R3	Pre + R3	

NS Fixation: 21 Wanatah

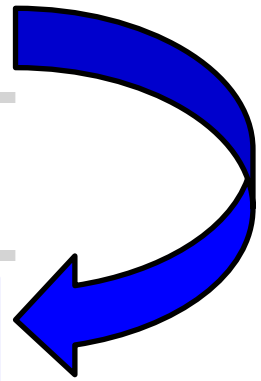
Fertilizer	Nitrogen	Sulfur	Yield
UTC	0	0	66.6
AMS	26	30	73.2
Gypsum	0	30	75.2
Urea	26	0	71.0
Full NS	150 + 150	15 + 15	73.3
	Pre + R3	Pre + R3	

20 Sulfur Timing: Vincennes

- **Sulfur**: 20 lb S/ac → AMS at PRE or V5
- **Nitrogen**: 17.5 lb N/ac → UAN at PRE or Urea at V5
- No Fertilizer x Timing interaction
- **Therefore, AMS benefit equal PRE to V5**

16 Sulfur Shotgun
at Vincennes
AMS at V3 → +5.3 bu

	Yield	
Untreated	48.7	b
N alone	50.3	b
AMS	54.0	a



Pooled across timings

Fluid Nitrogen and Sulfur Placement at Planting

- 2x2
- Coulter inject
- Conceal
- FurrowJet
- Seed firmer
- Dual surface band
- Inter seed pulse

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Salt Index

- Salt Index is a measure of the salt concentration that fertilizer induces in the soil solution. The SI of a material is expressed as the ratio of the increase in osmotic pressure of the salt solution produced by a specific fertilizer to the osmotic pressure of the same weight of $NaNO_3$, which is based on a relative value of 100.
- SI does not predict the exact amount of fertilizer material or a fertilizer formulation that could produce crop injury on a particular soil.
- Salt index varies by material in the mixture.
- Crops vary in their tolerance to concentrated salt solutions. Soybean is less tolerant than corn. Fluid fertilizers may produce a lower osmotic pressure in the soil solution than granular products of a similar grade.

John Mordvedt. 2001. Fluid Journal. https://fluidfertilizer.org

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Salt index of selected N and S fertilizers

Material and analysis	SI / weight of materials	SI per unit of nutrients
Ammonia, 82%N	47.1	0.572
Ammonium nitrate, 34%N	104.0	3.059
Ammonium sulfate, 21%N, 24%S	68.3	3.252
Ammonium thiosulfate, 12%N, 26%S	90.4	7.533
Urea, 46%N	74.4	1.618
UAN, 28%N (39% a. nitrate, 31% urea)	63.0	2.250
UAN 32%N (44% a. nitrate, 35% urea)	71.1	2.221

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Salt effect summary

- Salt effect is the change in osmotic pressure exerted by addition of concentrated salts.
- Soybean is less tolerant than corn to salt effect
- Solutions to salt effects are to reduce rate or increase fertilizer-seed distance.

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Schaffert Mfg.

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Fast Trac 2x2x2

Conceal, Precision Planting, Inc.

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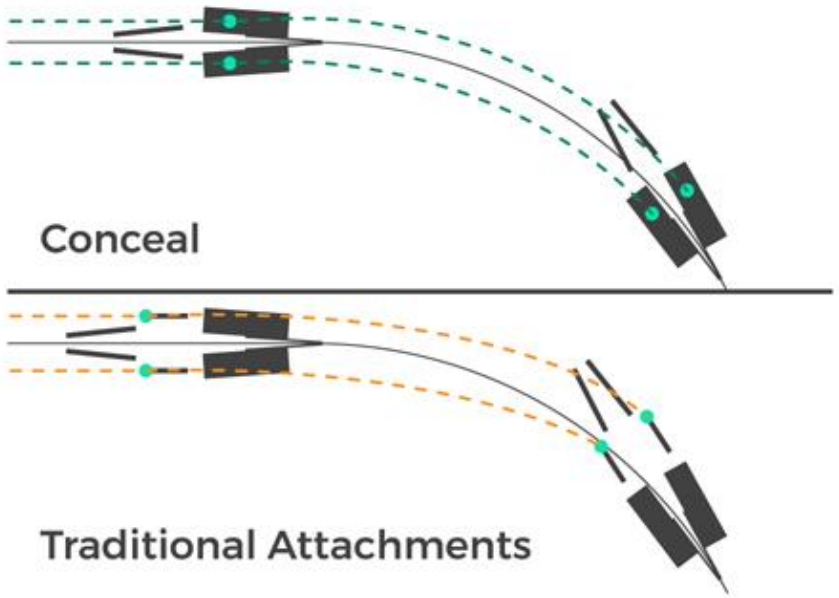

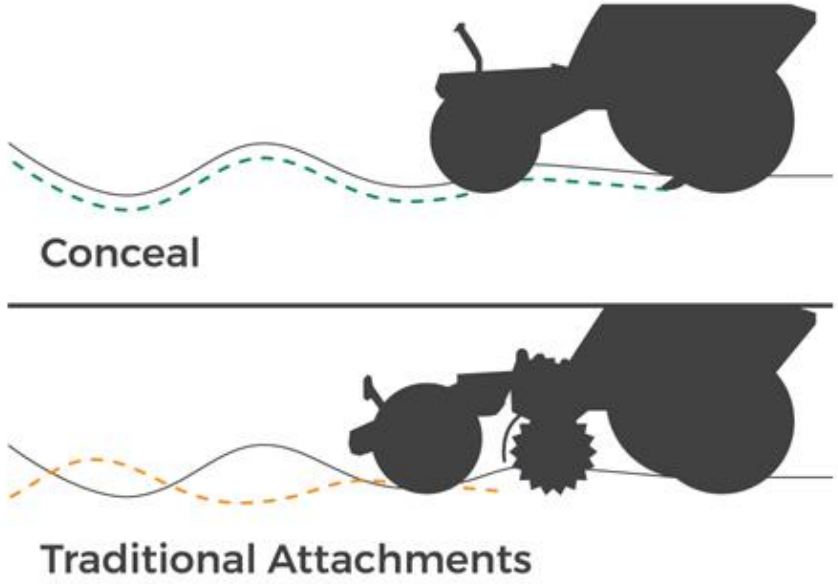

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Injected N vs Surface Banding

- 29 site years of data from 13 scientific articles showed 6.7 bushels per ac advantage from injecting N vs surface banding then incorporating.
- 43 site years of data from 13 scientific articles showed 12.2 bushels per ac advantage from injecting N vs surface broadcast (not incorporated).

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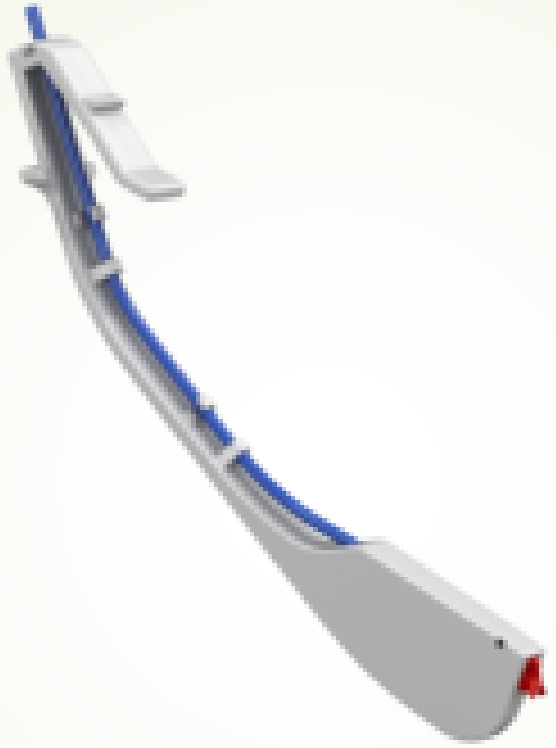

Keeton Seed Firmer
Precision Planting, Inc.

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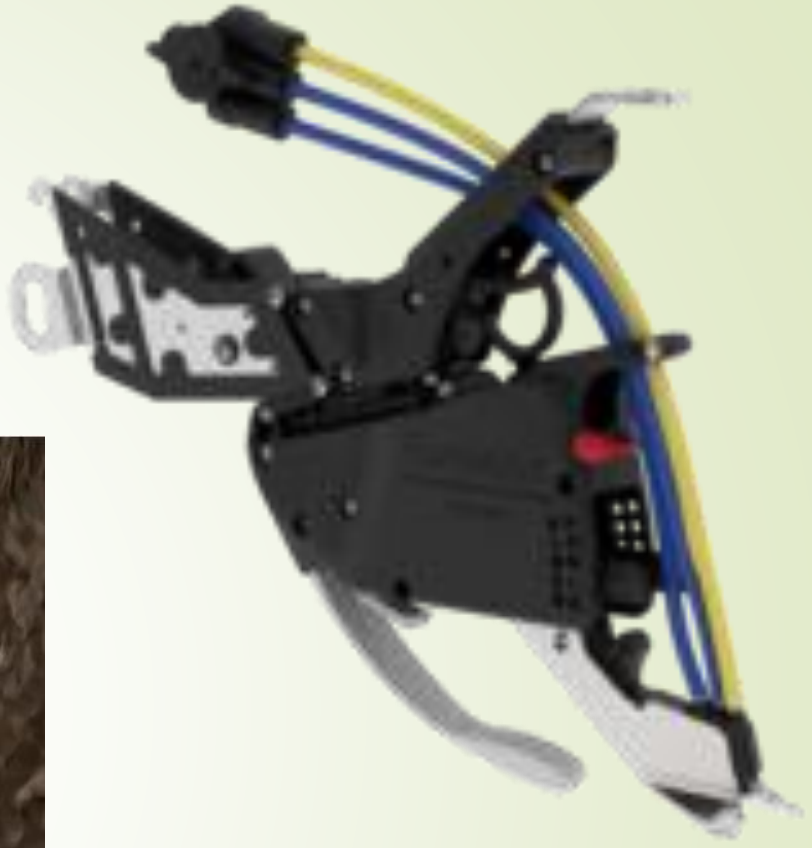

FurrowJet
Precision Planting, Inc.

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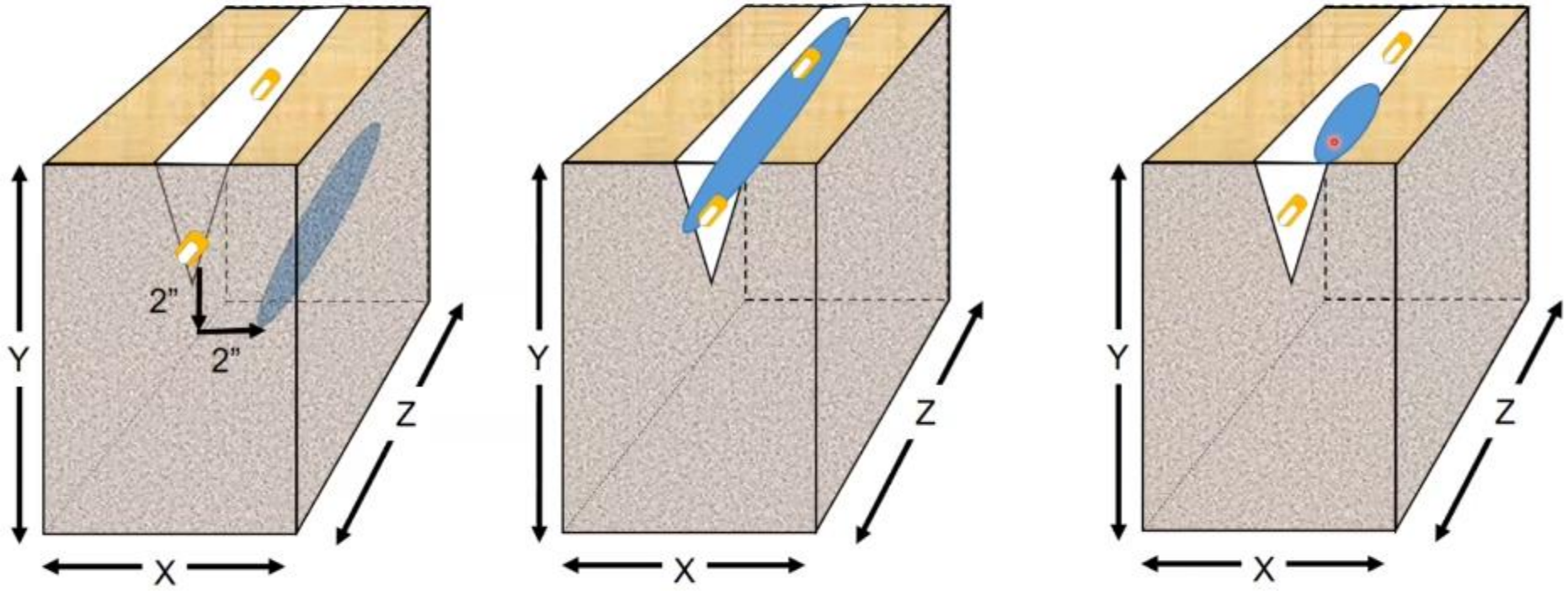
Placement options



Joshua M. McGrath, University of Kentucky

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Product	Rate	P_2O_5	Pulse Vol	Pulse Rate	Continuous Rate	Pulsed	Contin-uous	Seed-Fert Separation	Pulse Length
						-- Apparent SI --			
	g/a	lb/a	ml/seed	mg/cm	mg/cm	SI*mg/cm		----- in -----	
6-24-6	7.4	19.8	1.06	0.32	0.07	3.83	0.84	3.1	1.8
6-24-6	16.6	44.6	2.45	0.35	0.16	4.15	1.88	2.1	3.7
6-24-6	25.8	69.3	3.746	0.35	0.25	4.15	2.94	1.4	5.7
Poly	5.0	19.8	0.73	0.32	0.05	6.42	1.00	3.3	1.2
Poly	11.3	44.6	165	0.35	0.11	3.96	2.26	2.7	2.6
Poly	17.5	69.3	2.55	0.36	0.17	7.26	3.48	2.0	3.9
UAN	14.1	0.0	2.05	0.33	0.13	23.53	9.53	2.4	3.2

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Field verification

- The large study experienced environmental issues causing yield noise.
- A second (backup) study had limited results but some good inspiration for making the next year's full study more manageable. Tested 6-24-6 at 8.7 gpa and 10-34-0 at 5 gpa pulsed at 0.1, 1.4 and 2.8 inches from the trigger seed.

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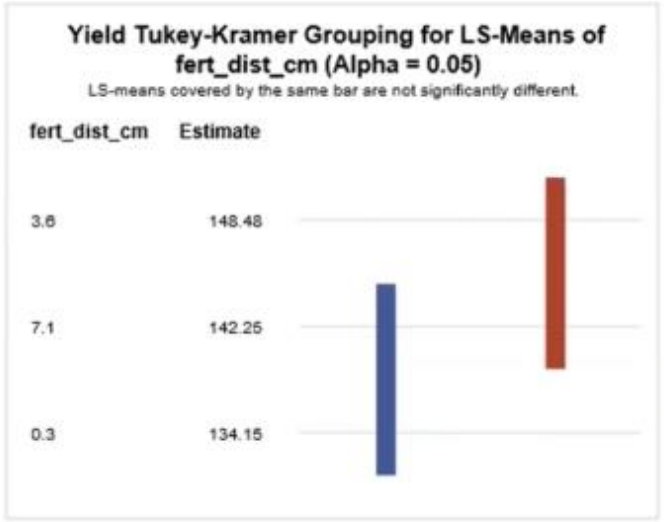
Distance from seed did matter



Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Product	1	172	1.41	0.2372
Distance (cm)	2	172	8.78	0.0002
Product*Distance	2	172	1.18	0.3092

Fertilizer Separation Least Squares Means								
Seed-Pulse Separation (cm)	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
0.3	134.15	2.9844	172	44.95	<.0001	0.05	128.26	140.04
3.6	148.48	2.9844	172	49.75	<.0001	0.05	142.59	154.37
7.1	142.25	2.9844	172	47.67	<.0001	0.05	136.36	148.14

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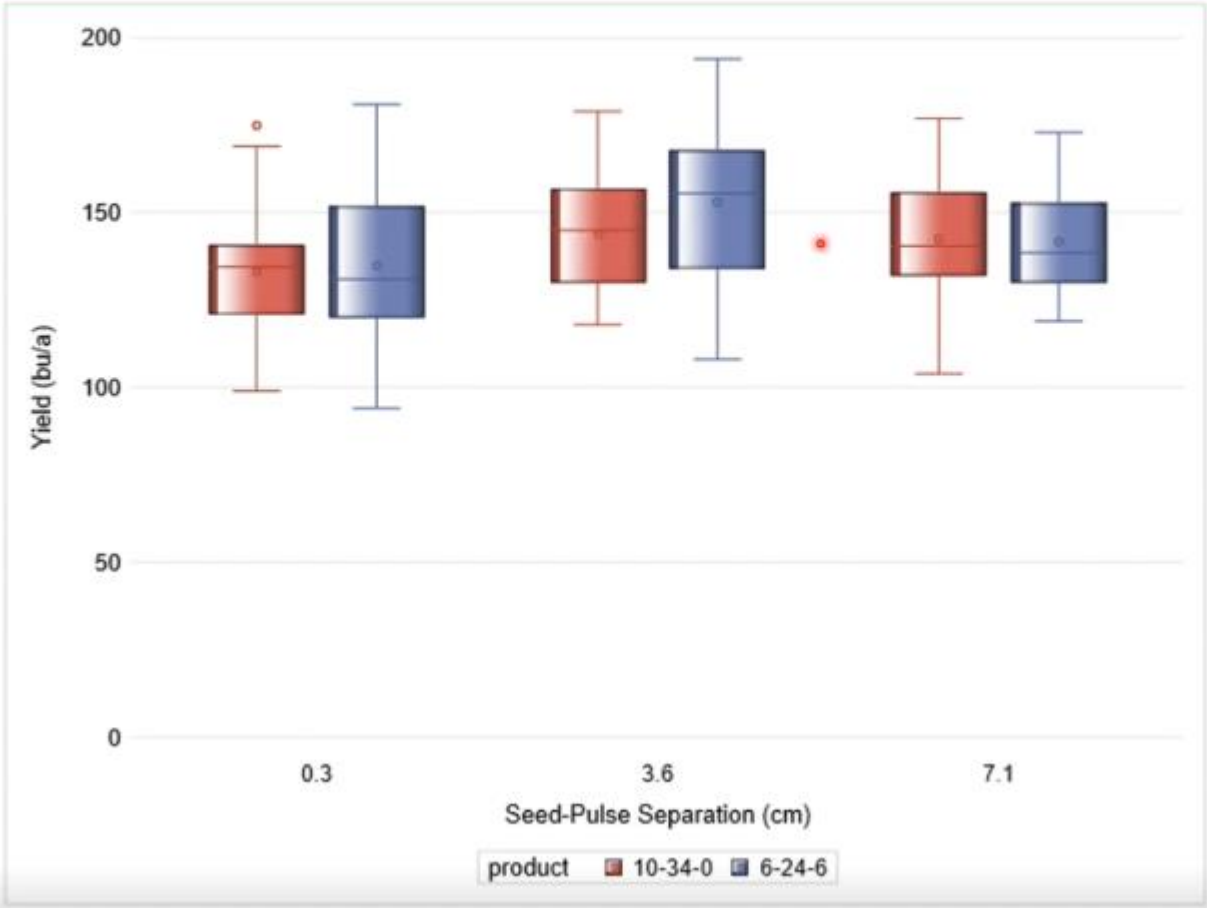
Product and Distance



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Starter Configuration - Corn

- 2x2 (Conceal)
  - 30-35 lb.N/ac
  - 3 gal./ac ATS
  - 1 qt./ac chelated 9-10% Zn
- Furrow Jet
  - 3-4 gal/ac 10-34-0 wings
  - 3 gal/ac low-salt In-Furrow
    - Insecticides, Fungicides, Biologicals, etc.
  - Multiple tanks, pumps and controllers

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B&M Crop Consulting, Coldwater, MI

Starter Fertilizer Furrow Jet Wings

- Furrow Jet Wings
  - 10-34-0 @ 0-6 gpa
- Furrow Jet In-furrow
  - Fungicide + Insecticide with water
- 2x2 Conceal
  - 28-0-0 8 gpa
  - 10-34-0 4 gpa
  - ATS 3 gpa
  - Zinc 1 qt

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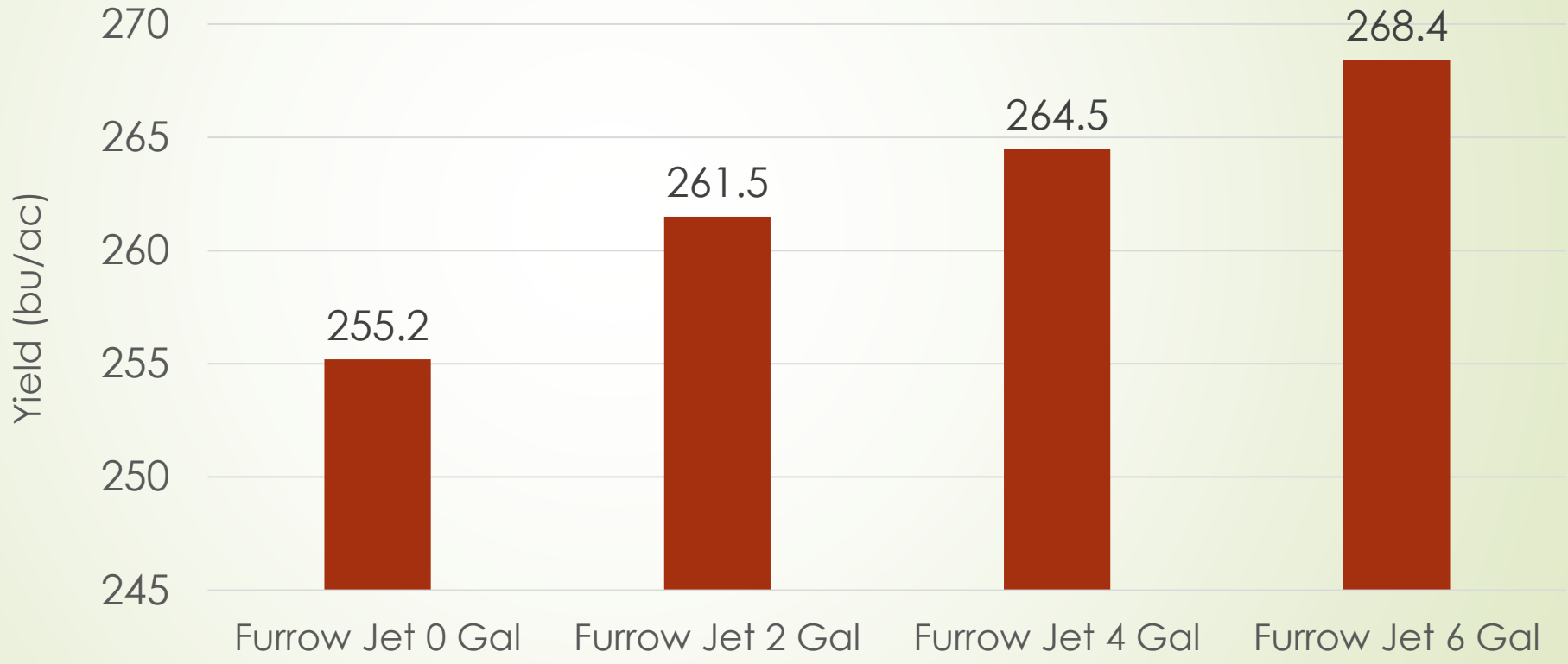
2020 Corn Furrow Jet 10-34-0 in wings. Union Ciy, MI. B&M Crop Consulting



Replicated, field size trials.

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2020 Corn Furrow Jet 10-34-0 in wings. Southern Michigan Multi Location Average Increase.
B&M Crop Consulting

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2020 Corn Furrow Jet 10-34-0 in wings. Southern Michigan Multi Location Net Profit Increase. B&M Crop Consulting

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2019-2020 B&M Furrow Jet Summary

- 2x2 plus Furrow Jet at 4 gpa had two-year average increase of 9 bushels/acre
- Furrow jet allowed for close placement of P without using low salt fertilizers.
- Lighter soils so more susceptible to salt damage.

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Summary - Soybean response to at planting N+S

- Soybean crops cannot rely solely on atmospheric S. (5-7 lbs. S/ac)
- Organic matter contributes ~ 3-5 lbs. S/ac-%OM
- Soybean uptake is about 0.3 lbs. S/bushel
- There is a variable response to at-planting N. Products like ATS & AMS already have a nitrogen component. More likely to occur in cool soils or wetter conditions.
- Early sulfur may aid in nodulation.
- Fertilizer-seed separation must be wide enough to avoid salt effects.
- Applications beyond optimum are not likely to increase yield and may reduce yield
- Early applications are best (prior to V5-V6).

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Summary - Corn response to at planting N+S

- Corn uptake is about 0.12 lbs. S/bushel (24 lbs./200 bushels)
- Corn cannot rely solely on atmospheric S. (5-7 lbs. S/ac)
- Organic matter contributes ~ 3-5 lbs. S/ac-%OM
- Corn is a large consumer of N. N applied at planting can help even out stands and produce stronger crops quicker. Especially in cooler soils. Sulfur helps chlorophyll and protein production, and an early shot may help the crop until S mineralization accelerates in warmer soils.
- Fertilizer-seed separation must be wide enough to avoid salt effects.
- Applications beyond optimum are not likely to increase yield and may reduce yield
- Early applications are best but sidedress application (prior to V5-V6) are also effective. Anecdotal evidence supports sulfur additions up to VT in certain corn production situations but corroborating research is absent.

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